Remote Sensing of Liquid Water and Ice Cloud Optical Thickness and Effective Radius in the Arctic: Application of Airborne Multispectral MAS Data

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ABSTRACT

A multispectral scanning spectrometer was used to obtain measurements of the bidirectional reflectance and brightness temperature of clouds, sea ice, snow, and tundra surfaces at 50 discrete wavelengths between 0.47 and 14.0 μm. These observations were obtained from the NASA ER-2 aircraft as part of the First ISCCP (International Satellite Cloud Climatology Project) Regional Experiment (FIRE) Arctic Clouds Experiment, conducted over a 1600 km $\times$ 500 km region of the north slope of Alaska and surrounding Beaufort and Chukchi Seas between 18 May and 6 June 1998. Multispectral images in eight distinct bands of the Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS) were used to derive a confidence in clear sky (or alternatively the probability of cloud) over five different ecosystems. Based on the results of individual tests run as part of this cloud mask, an algorithm was developed to estimate the phase of the clouds (liquid water, ice, or undetermined phase). Finally, the cloud optical thickness and effective radius were derived for both water and ice clouds that were detected during one flight line on 4 June.

This analysis shows that the cloud mask developed for operational use on MODIS, and tested using MAS data in Alaska, is quite capable of distinguishing clouds from bright sea ice surfaces during daytime conditions in the high Arctic. Results of individual tests, however, make it difficult to distinguish ice clouds over snow and sea ice surfaces, so additional tests were added to enhance the confidence in the thermodynamic phase of clouds over the Chukchi Sea. The cloud optical thickness and effective radius retrievals used three distinct bands of the MAS, with a recently developed 1.62- and 2.13-μm-band algorithm being used quite successfully over snow and sea ice surfaces. These results are contrasted with a MODIS-based algorithm that relies on spectral reflectance at 0.87 and 2.13 μm.

1. Introduction

A knowledge of cloud radiative properties and their variation in space and time is especially crucial to the understanding of the radiative forcing of climate. High quality multispectral imagery acquired from high-altitude aircraft or satellite platforms is the most efficient and reliable means of fulfilling these observational requirements. Between 18 May and 6 June 1998, the National Aeronautics and Space Administration (NASA) ER-2 high-altitude research aircraft conducted 11 research flights over the north slope of Alaska and the surrounding Beaufort and Chukchi Seas as part of the First ISCCP (International Satellite Cloud Climatology Project) Regional Experiment—Arctic Clouds Experiment (FIRE ACE). The NASA ER-2 aircraft was equipped with seven sensors, among which the Moderate Resolution Imaging Spectroradiometer (MODIS) Airborne Simulator (MAS; King et al. 1996) was designed to obtain measurements that simulate those obtained from MODIS, a 36-band spectroradiometer launched aboard the Earth Observing System (EOS) *Terra* (King and Herring 2000) and *Aqua* (Parkinson 2003) spacecraft.

The strategy for FIRE ACE included spaceborne remote sensing (polar-orbiting satellites), high-altitude remote sensing (NASA ER-2 at ~20 km), lower-altitude remote sensing and in situ measurements [University of Washington CV-580, National Center for Atmospheric Research (NCAR) C-130Q, and Canada's National Research Council Convair 580 (NRC CV-580) aircraft], ground-based measurements (radiation, clouds, meteo-

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